A practical way to detect and quantify the 3D radiative effects in passive cloud property retrievals: theoretical basis and feasibility study

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Most operational remote sensing algorithms are based on the computationally efficient 1D radiative transfer (RT) theory, while in reality, the RT process is intrinsically 3D. The 1D RT is based on two fundamental assumptions: the "plane parallel approximation" and "independent pixel approximation". When actual cloud fields deviate from these assumptions, the cloud radiative properties derived from the 1D RT simulations will be different from the observed values, which is known as the "3D effects" in radiative transfer and cloud remote sensing. As a result, the retrieved cloud properties will be biased depending on the magnitude of the 3D effects and also on the retrieval technique. Take, for example, the bi-spectral cloud optical thickness (COT) and cloud-droplet effective radius (CER) retrieval. The so-called "illuminating effect" can lead to an overestimation of the COT and underestimation of the CER, while the opposite shadowing effect leads to an underestimation of the COT and overestimation of the CER. Despite substantial efforts made in the past, there is still a lack of practical ways to detect and quantify the 3D effects at the pixel level.

Recently, we have developed a theoretical framework that uses a combination of polarimetric and radiometric measurements to detect the pixels of a radiometric image of clouds that are affected by the 3D radiative transfer effects. Moreover, with the aid of synthetic cloud fields from the large-eddy simulation model [1,2] and 3D radiative transfer simulations [3], we have successfully demonstrated how the corrected radiances can significantly improve the statistics of cloud property retrievals.

References

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